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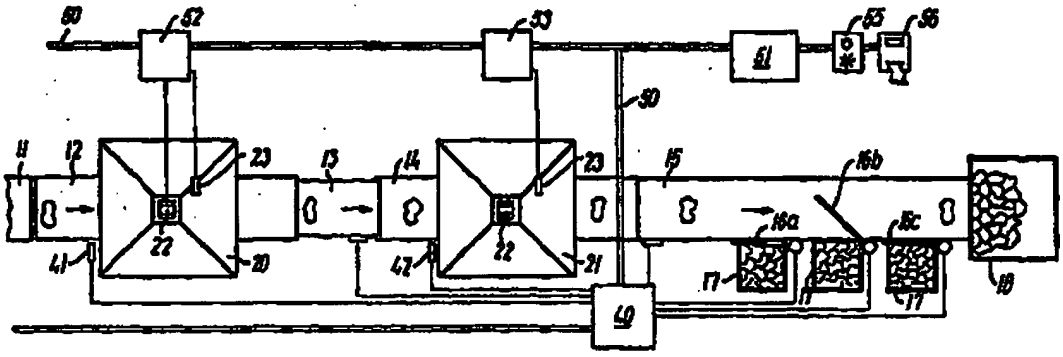

(57) Abstract

With a view to quality control or sorting of pieces of meat, a system is used which on-line determines quality characteristics of the pieces of meat. The system comprises a conveyor with a belt (12, 13, 14) for conveyance of the pieces of meat (2), an arrangement of illumination (20, 21) located over the belt for illumination of the pieces of meat, a colour camera (22) located in the arrangement for recording of three frames of the pieces of meat in the red, green, and blue spectral region, and data equipment (51, 52, 53) for storage of the frames in the form of RGB-light values, analysis of the stored images and determination of the quality characteristics of the pieces of meat on the basis of the analysis. The system includes a three-chip CCD-colour camera which records frames in the red, green, and blue region, each on an individual chip, and the system is designed to record and store interdependent RGB-light values which originate from the same physical (actual) part of the piece of meat. By means of the system insufficient fat trimming as well as areas of PSE and bleedings can be detected on pieces of meat which are to be used for the production of cooked hams or other products. The system can be arranged so that it has a speed of detection which is acceptable for practical conditions of production, e.g. one piece of meat a second.

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System, apparatus and method for on-line determination of quality characteristics of pieces of meat, and arrangement for illumination of pieces of meat.

The present invention relates to a system for on-line determination of quality characteristics of pieces of meat for quality control or sorting, the system comprising: a conveyor with a belt for conveyance of the pieces of meat, an arrangement of illumination placed over the belt for illumination of the pieces of meat, a colour camera placed in the arrangement for recording of three frames of the pieces of meat in the red, green, and blue spectral region, and data equipment for storage of the frames in the form of RGB-light values, analysis of the stored frames, and determination of quality characteristics of the pieces of meat on the basis of the analysis.

Cooked hams are made of several small muscles which are filled into a mould, casing or tin and cooked into a coherent product which can be cut into thin slices to be used e.g. in sandwiches. Mainly four different types of pork cuts are used, namely chump, top side, silverside and knuckle. The muscles are delivered to the site of production in containers typically containing 500 – 1,000 kg of meat. Spot tests are taken to check the muscles, some samples of each batch being appraised visually at the site of production for any defects, such as insufficient fat trimming of the surface of the muscle, bleedings, and blood stains in the muscle, PSE-stains in the meat and other undesirable defects (PSE means Pale, Soft, Exudative). Besides, visits of inspection are paid to the suppliers.

It is important to keep the defects mentioned at a low level, as they may be the cause of significant waste by the slicing of the ham at the consumer, and they may even cause the buyer of a quantity of hams to return the delivery because of dissatisfaction with the quality.

Correct fat trimming of the surface of muscles are important to the customer's visual impression, and too much fat may also make it difficult to comply with a declaration stating 98% fat-free, lean meat. Bleedings in the meat are clearly visible in the finished product, as the areas turn darker during the heat treatment and this gives the product a heterogeneous appearance. PSE in the muscles cause problems, because after the cooking process the meat is so loose in texture that it cannot be sliced correctly. This reduces the

yield of the slicing significantly. Moreover, PSE causes an increased cooking loss in the production of cooked hams.

An investigation has shown that over one half of the muscles in a production may have trimming defects as regards fat. Therefore, there is a need for improved check of the raw materials used in the production. However, this is only obtainable by examining each and every piece of meat for common defects, such as insufficient fat trimming, bleedings, and PSE.

A manual check of each piece of meat seems to be extremely labour consuming and it is subject to the fluctuating appraisal capability of the checkers. It is tedious to examine pieces of meat for hours every day, and moreover, different checkers will appraise differently.

An objective check by means of video systems could be another option. In that connection mention shall be made of GB–A–2.144.533 (Analytical Instruments Ltd.) which describes an image–analyzing system for determination of the percentage of fat in pieces of meat placed on a black support. The system includes a video camera the signal output of which is connected with one input of a comparator. When the video signal exceeds a threshold value on the other input of the comparator, the comparator starts a counter, the final value of which after an image scanning reflects the percentage of light areas of the image, e.g. areas of fat. The value of the counter is stored in a memory. The threshold value is then reduced, and in another image scanning the percentage of areas which are lighter than the support is found, i.e. the total area of meat and fat. The area of fat is eventually determined as the difference between the values of the counter obtained by the first and the second image scanning.

The system preferably employs a monochrome video camera, but there is also a description of an embodiment which comprises a colour video camera with outputs for a red, green and blue video signal. The signals are fed to a comparator with an automatically changeable threshold value. The output signal of the comparator is stored in a red, green and blue bit plane, the data of which can be transferred to a computer for further processing.

If the difference between the meat surfaces and the fat surfaces is sufficiently distinct, the system described can distinguish these surfaces from each other, and in these instances the system can be used for determination of the percentage of fat on meat. However, the system is not capable of distinguishing occurrences which differ from each other to a less distinct degree, e.g. fat from pale meat.

GB-A-2.187.281 (Analytical Instruments Ltd.) describes a similar system for determination of the percentage of fat on meat. A red filter, which is placed in one half of the field of view of the camera, allows detection of total areas of meat and fat. A green filter, which is placed in the other half of the field of view, detects the areas of fat. A conveyor belt conveys the meat through the field of view in such a way that all meat which is measured in one half of the field of view is also measured in the other half.

The described video systems provide information of the percentage of fat, but no information of occurrences of PSE, bloody meat or other quality characteristics of the meat, e.g. the location of the areas of fat on the pieces of meat. Furthermore, there may be problems synchronizing the images in connection with recording images of meat located on a belt in motion. Therefore, such systems are inadequate for checking of meat in the mentioned ham production.

An unpublished preliminary investigation with recording of images of meat with PSE-defects and bleedings by means of a usual colour video camera with red, green and blue line filters disclosed that even by colour recordings it is very difficult to distinguish and differentiate PSE-areas from pale meat and bleedings from dark meat. This applies both by visual viewing of the images on a monitor and by a usual digital analysis of an image stored in a memory. The investigation also disclosed that the time consumption for a cycle of recording and analyzing is so big that the system cannot be used for a running objective check of each and every piece of meat in a production of ham.

The purpose of the present invention is to provide a system which is substantially better than the known systems at determining on-line quality characteristics of pieces of meat which are important for the production of ham, in particular insufficient trimming of fat, occurrences of PSE and bloody areas on the meat.

This object is attained by using a three-chip CCD-colour camera which is designed for recording a colour image composed of RGB-light values, in which image the interdependent RGB-light values originate from the same actual micro surface of the piece of meat, and by storing in data equipment the values registered on the individual chips in the camera for subsequent analysis. In this way an image which is particularly suitable for analysis having an extreme "colour-true reproduction" is recorded and stored, and the recording and storage process is performed in a short time using three chips in the CCD-camera.

The system according to the present invention is characterized in that it comprises a three-chip CCD-colour camera which records frames in the red, green and blue region, each on an individual chip and that the system is designed to record and store interdependent RGB-light values which originate from the same physical (actual) part of the surface of the piece of meat.

The system according to the invention is considerably better than the known systems at distinguishing occurrences which are only slightly different in colour from each other. It is even capable of determining quality characteristics on-line and while the meat is in motion, since three frames can be recorded and stored simultaneously and a CCD-camera as a matter of course can work with a short time of exposure.

In other words, insufficient fat trimming as well as comprehensive areas of PSE and bleedings can be detected to a satisfactory extent, and it is possible to operate at a speed of detection which is acceptable for practical purposes (one piece of meat per second, or from 1,500 kg to 5,000 kg of meat per hour, depending on the type of meat).

In a preferred embodiment the camera is designed to record interdependent RGB-light values simultaneously. In this way the influence that the motion of the pieces of meat by the conveyor may have is eliminated. The time used for recording and storage is hereby shorter.

The data equipment may include a three-dimensional table that for each accepted combination of RGB-light values refers to a certain type of surface, e.g. fat, PSE or bloody

meat. A certain type of surface will typically constitute one or a few spaces in the table. The non-accepted combinations of RGB-light values are for instance the background, rim areas of the meat or indeterminable areas.

By applying such a three-dimensional table you obtain a finer distinction between the different types of surface than by the known application of threshold values, as the total colour space is divided so to speak by curved, closed surfaces which each surrounds a space for each type of surface.

A table makes it possible to use a higher percentage of the stored light values, and the light-value combinations which have a poor or no correlation with the types of surface searched for are eliminated immediately, which will save data power during the subsequent analysis. A reference to the table gives direct information of the type of surface of a certain pixel, so that the identification process becomes extremely fast. Therefore, the table makes it possible to determine the type of surface quickly and precisely.

The data equipment may more specifically include an application programme which compares stored, interdependent RGB-light values with a three-dimensional table installed in the data equipment, which table refers to a certain type of surface for each accepted combination of RGB-light values and assigns to each pixel of the composite image that contains an accepted combination of RGB-light values the table's code for type of meat.

The data equipment may also include an application programme which repeats the procedure for a significant part of the interdependent RGB-light values which originate from the surface of a piece of meat, segments the area of the composite image that depicts the surface of the piece of meat into areas with different types of surface, and then assigns the piece of meat to a class of quality with a view to quality control or sorting.

The data equipment may include an application programme for demasking of the piece of meat and omission of the rim area of the piece of meat.

Furthermore, an application programme may be included which determines whether the image recorded shows one or the other side of the piece of meat, e.g. a muscle, and which then selects the corresponding table.

It is also possible to install an application programme which determines the muscle type, e.g. whether it is chump, top side, silverside or knuckle, and which then selects the corresponding table. This may be important if there are different muscle types and these are delivered in a mixed-up state from a conveyor belt or in the batch which is to be examined.

The camera may be designed to record a frame in the region from 390 to 440 nm, a frame in the region from 500 to 570 nm, and a frame in the region from 620 to 700 nm. In that connection the blue region is displaced towards the UV-region and the red region towards the NIR-region in order to provide better detection quality. The camera can also operate within the usual regions of 420-500 nm (B), 500-570 nm (G), and 570-640 nm (R).

The camera used is preferably provided with an electronic shutter the shutter speed of which set at 1/500 second or below; hereby the resolution and the "true colour" of the recordings are retained even though the material is in motion.

The pieces of meat can be illuminated by visible light and/or UV-light. Preferably, broad-spectrum light is used, covering the entire visible region. The illumination can be continuous or impulsive (flashlight).

Spectro-neutral light improves the chance of detecting different types of occurrences. Diffuse illumination reduces the formation of shadows and reflections of the sources of light on the surface of the meat. Therefore, the arrangement of illumination is preferably of a type which gives a diffuse, spectro-neutral foreground illumination of the pieces of meat.

The pieces of meat, which are conveyed under the arrangement of illumination, may have an illumination of more than 1000 lux, preferably more than 5000 lux, in order to provide a good definition in depth and to reduce the noise in the electronic image.

The pieces of meat under the arrangement of illumination may be exposed to stronger light on the sides than on the top, which faces the camera, so that the rim area presents itself with the same brightness as the mid section, seen from the standpoint of the camera.

The arrangement of illumination may comprise a downwards–open house, along the walls of which are placed light sources, particularly fluorescent tubes, and it may comprise devices for forced air circulation around the light sources. Besides, devices for tempering of the circulating air may be provided. This stabilizes the emission of light from the light sources, both as regard spectrum and intensity.

The arrangement of illumination may contain devices which adjust the output of the light sources and/or the composition of colour at a constant level, preferably the voltage to DC–operated fluorescent tubes, operated by HF–choke coils.

In the field of view of the camera there may be placed one or several objects, the surface of which serves as a reflection and/or colour reference, so that the recorded images can be corrected currently for errors which are due to instability in the light sources or the camera. The object of reference may comprise three surface fileds, one of which is selected as reflection and/or colour reference based upon an estimate of the least soiling.

The camera and the data equipment may be designed to record and store interdependent RGB–light values at more than 100 levels, e.g. 250 levels. By application of many levels the colour resolution of the system is improved, so that the system is better capable of distinguishing undesirable occurrences from "normal" surface types.

Down–stream from the arrangement of illumination the system may include a second, corresponding arrangement of illumination with a camera, and the conveyor may have a section of the belt between the arrangements which is designed to turn a piece of meat around so that the side which was hidden from the camera of the first arrangement is facing the camera of the second arrangement. The control and sorting are substantially better when both sides of the piece of meat are examined.

Along the conveyor belt, which is placed after the equipment for image recording, there may be spaces allowed for reservoirs for meat with deviating qualities, and opposite every space there may be a guiding plate or the like which, controlled by a sorting device, can swing across the belt. At the end of the conveyor there may be a reservoir or another conveyor for pieces of meat which do not possess or only to an insignificant degree possess deviating qualities.

The conveyor is preferably designed to be running while an image is being recorded. The camera and the data equipment may be designed to record and process images of a new object at intervals of less than five seconds, so that the system can keep up with the ordinary production rate.

The conveyor may consist of several sections, the speed of which can be adjusted currently and independently of each other, so that the pieces of meat are conveyed under the camera at a uniform pace and at the necessary space.

The system may include a sensor located at the conveyor which is designed to trigger the recording of an image.

The system may include a section for one-by-one conveyance of pieces of meat from a supply container to the up-stream end of the conveyor.

The invention also relates to a method for on-line determination of quality characteristics of pieces of meat for quality control or sorting, the method comprising: conveyance of the pieces of meat by means of a conveyor with a belt, illumination of the pieces of meat by means of an arrangement of illumination placed over the belt, recording of three frames of the pieces of meat in the red, green and blue region by means of a colour camera placed in the arrangement, storage of the frames in the form of RGB-light values, analysis of the stored frames, and determination of the quality characteristics of the pieces of meat on the basis of the analysis.

The method according to the invention is characterized in that frames in the red, green and blue region are recorded, each on an individual chip in a three-chip CCD-colour camera

and that interdependent RGB–light values which originate from the same physical (actual) part of the piece of meat are recorded and stored.

According to a preferred embodiment of the invention, interdependent RGB–light values are recorded simultaneously.

According to another embodiment of the method, stored, interdependent RGB–light values are compared with a three–dimensional table installed in a data equipment, which refers to a certain type of surface for each accepted combination of RGB–light values, and each pixel of the composite image which has an accepted combination of RGB–light values are assigned the table's code for type of meat.

This procedure can be repeated for a significant part of the interdependent RGB–light values which originate from the piece of meat, the area of the composite image that depicts the piece of meat can be segmented in areas with different types of surface, and the piece of meat can be referred to a quality class with a view to quality control or sorting.

The light sources of the arrangement of illumination may be kept at a constant temperature by forced air circulation around the light sources.

In a special embodiment three additional frames of the piece of meat are recorded by means of a second camera, located down–stream from the arrangement of illumination, provided with a similar arrangement of illumination, in such a way that the side of the piece of meat which was hidden from the camera of the first arrangement is facing the camera of the second arrangement before the image recording.

The invention also relates to an apparatus for on–line determination of quality characteristics of pieces of meat for quality control and sorting, the apparatus comprising: a conveyor with a belt for conveyance of the pieces of meat, an arrangement of illumination placed over the belt for illumination of the pieces of meat, a colour camera placed in the arrangement for recording of three frames of the pieces of meat in the red, green and blue region, and data equipment for storage of the frames, analysis of the frames and determination of the quality characteristics of the pieces of meat based upon the analysis.

The apparatus is characterized in that down-stream from the arrangement of illumination it comprises a second, corresponding arrangement of illumination with a camera, and that the conveyor between the arrangements has a belt section which is designed to turn around a piece of meat so that the side which was hidden from the camera of the first arrangement is facing the camera of the second arrangement. Control or sorting becomes significantly more secure when pieces of meat are examined on both sides by means of this apparatus.

A simple way of providing this turning is by placing the belt section at the up-stream end in a lower position in relation to the belt which passes under the first arrangement.

The invention also relates to an arrangement for illumination of pieces of meat which are conveyed on a conveyor belt in connection with recording of images of the pieces of meat, which arrangement comprises a downwards-open house, along the walls of which are placed light sources. The arrangement is characterized in that it is provided with devices for forced air circulation around the light sources. This will stabilize the emission of light from the light sources, both regarding spectrum and intensity.

Preferably, the arrangement comprises thermostatically controlled ventilators and/or heating elements.

The invention is preferably used in connection with the production of a meat product, composed of several small pieces of meat, which are cooked in mould, casing or tin. All of the small pieces of meat are checked for excess fat, comprehensive areas of PSE, and comprehensive bloody areas while they are being conveyed by the belt, and pieces of meat with deviating characteristics are sorted out before the approved pieces of meat undergo further processing.

The invention can generally be used for examination of one piece of meat at a time or for examination of several pieces of meat at a time, e.g. a batch of meat pieces, placed in a box, which is conveyed by the conveyor.

The examination can include the following types of meat:

- boned hams and fore-ends,
- trimmings from pigs, sheep and cattle,
- cuts of pork and beef
- poultry and fish, and
- other types of meat.

Above, mention is especially made of sorting and quality control on the basis of fat, PSE, and bleedings, but the invention can also be used in connection with other types of occurrences, e.g. for detection of rind, sinews, gristle, bone, jelly, or foreign bodies such as parts of plastic or metal.

The invention is explained more specifically in the following with reference to the drawings, in which:

Fig. 1a is a top plan view of the front section of a system for detection of pieces of meat with deviating characteristics and sorting of the pieces of meat into four different categories,

Fig. 1b is a top plan view of the rear section of the system,

Fig. 2a is a side elevational view of the section of the system shown in Fig. 1a in a simplified representation,

Fig. 2b is a side elevational view of the section of the system shown in Fig. 1b,

Fig. 3 is a perspective view of an arrangement of illumination used in the system,

Fig. 4 shows spectra of different types of meat,

Fig. 5 shows deviations of the types from the mean spectrum,

Fig. 6a–6c shows examples of localities for dark (M) and bloody (B) meat (outside of chump),

Fig. 7a–7c shows examples of localities for pale meat (L) and PSE–meat (P) (outside of silverside), and

Fig. 8a–8c shows examples of localities for membranes (H) and fat (F) (outside of chump).

The front section of the system (Fig. 1a) serves for separation and one–by–one conveyance of pieces of meat to the rear section of the system (Fig. 1b). The front section includes a

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- trimmings from pigs, sheep and cattle,
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The front section of the system (Fig. 1a) serves for separation and one–by–one conveyance of pieces of meat to the rear section of the system (Fig. 1b). The front section includes a

feed hopper 1, which can hold 1000 kg of muscles or meat cuts 2, which are tipped into the hopper 1 from a transport container. In the tip of the hopper there is a lock arrangement 3, the aperture area of which can be adjusted so that the muscles can pass through the lock more or less unimpeded. Immediately after the lock arrangement there is a dosage wheel 4 with finger-shaped carriers which project radially from the centre of the wheel. The speed of the wheel can be adjusted so that the muscles being conveyed by the carriers are released to a subsequent conveyor belt 5 at a certain pace, which is set by control means of the system. A flap 6 which is freely pivoting around a horizontal axle, which is located over the conveyor belt 5, ensures that the muscle is straightened out, so that it lies flat down on the belt. Located along the sides of the conveyor belt 5 are four alignment devices 7, each including a guiding plate which is hinged on vertical pivots and which against the force of built-in springs can swing backwards from the position of rest shown when a muscle 2a being conveyed on the conveyor belt hits the guiding plate. The two alignment devices on the up-stream part of the belt mainly serve to guide the muscles towards the centre line of the belt, whereas the two alignment devices located on the down-stream part mainly have the purpose of turning the muscles around so that they lie lengthwise in the longitudinal direction of the belt.

Over the conveyor belt 5 there is a sensor 8 which informs the control system when there is a muscle under the sensor. In view of for instance the sensor signal the speed of the belt can be adjusted. This ensures a more even pace of muscles falling down onto a subsequent conveyor belt 9. Among other things this belt serves as a buffer. The main function of the belt is, however, to rearrange the muscles so that they are positioned lengthwise across their direction of conveyance. The speed of the belt can also be adjusted and the belt is provided with a sensor which registers when a muscle is transferred to a buffer belt 11, as shown to the right in Fig. 1a.

The muscles are transferred one by one from the buffer belt 11 to the rear section of the system (Fig. 1b), being transferred to a conveyor belt 12, as shown in the left-hand side of Fig. 1b. The rear section of the system (Fig. 1b) serves to record images of the individual pieces of meat and to sort these into different categories on the basis of the analyzed images. For the recording of the images there are a first and a second arrangement 20 and 21, which are similar in design. The design and function of the arrangements appear

in particular from the explanation in connection with Fig. 3. Mention should be made that each arrangement includes a camera 22 and that it is provided with a sensor 23 which detects when a muscle being conveyed on the belt below is located in the field of view of the corresponding camera 22. The sensor then triggers a sequence of image recording and image processing in equipment which is connected with the camera.

After the recording has been made in the arrangement – it takes place with the belt 12 running – the muscle is conveyed over the down–stream end of the conveyor belt, falling down onto a intermediate belt 13, as is best seen from Fig. 2b. During this fall the muscle does a "somersault" so that it hits the belt 13 with the side which used to be the top side. The side which used to be lying on the conveyor belt 12 is now facing upwards, permitting an image recording of the other side of the muscle in the second arrangement 21, which is placed over a conveyor belt 14 corresponding to the belt 12.

After the recording in the arrangement 21 the muscle is transferred to yet another conveyor belt 15, from which it can be sorted, on the basis of the image recordings, into one of four muscle categories. Along one side the belt is provided with three pivoting guiding plates 16a, 16b, and 16c (Fig. 1b) which, controlled by signals from a PLC–control unit 40, can be swung across the belt 15, so that further conveyance of the muscle on the belt is stopped and the muscle is led over the edge of the belt. Here it falls down into one of three vessels 17, which are placed opposite the respective guiding plates. The vessels are intended for muscles with insufficient fat trimming, muscles with PSE, and muscles with bloody areas. If none of the guiding plates has swung across the belt, the muscle will proceed over the down–stream end of the belt and fall down into a vessel 18, which is intended for muscles without deviating characteristics.

The PLC–control unit 40 sees to that the muscles 2 are dosed from the hopper 1 and conveyed to the arrangements 20 and 21 at a regular pace which is in accordance with the capacity of the arrangements to record and process images of the muscles, the unit regulating the aperture area of the lock 3 and the speed of the wheel 4 and the conveyor belts 5,9,11,12,13,14. The control unit also keeps track of where the muscles which pass a sensor 41 (Fig. 1b) are subsequently located in the transport system. Each muscle is

assigned a serial number when it passes the sensor 41, and in this way it is followed all the way until it is in one of the four vessels 17,18.

Via a network 50 the PLC-control unit itself receives a signal as to the category of the current muscle which arrives at the up-stream end of the belt 15, and as mentioned it serves the guiding plates 16a, 16b, 16c in accordance with the signal (normal, insufficient fat trimming, PSE or bloody areas). Two sensors 41,42 are connected with the PLC-unit 40, so that it can pace the muscles through the arrangements 20 and 21.

The network 50 is served by a main data processing unit 51, and in addition to this and the PLC-unit 40 it includes two image processing units 52 and 53, which are each connected with its own individual camera 22, a terminal 54 for communication with an operator via a keyboard, and a monitor and an alarm box 55 calling the attention of the operator when the hopper 1 needs refilling or a vessel 17,18 is full, and a printer 56 for printing of labels with information of the meat collected in one of the vessels 17,18.

Briefly, the main data processing unit 51 functions in the way that it receives instructions from the PLC-unit 40 that a muscle is on its way into one of the arrangements 20 or 21. Via the network 50 the data processing unit sends a signal to the respective image processing unit 52, 53 to go into active position for an image recording cycle. This is started when the respective sensor 23 detects a muscle in the field of view of the corresponding camera 22, which simultaneously records three images of the muscle in the blue, green and red region. The images are registered and processed in the unit 52, 53 connected with the camera, with a view to finding areas with fat, PSE or bleedings. Each unit comprises a frame-grapper storing the images recorded in the three different wave-length regions, and a RISC-processor in direct communication with the frame-grapper for digitizing and processing of the images. Furthermore, there are different programmes with algorithms and tables for demasking of the image, interpretation of the pixels (cf. Example 3 below) and division of the composite image into segments each representing its own type of surface (normal meat, fat, PSE-meat, and bloody meat). The result is sent to the data processing unit 51, which sums up the areas of the different types of surface, after the images of both sides of the muscle have been recorded and analyzed as stated.

If the total area of undesirable occurrences (fat, PSE, bloody meat) exceeds some criteria which have been installed in the data processing unit 51, a message is sent via the network 50 to the PLC–unit 40 to swing the corresponding guiding plate 16a, 16b, 16c across the belt 15, so that the muscle can fall down into the vessel 17, which is intended for muscles with the muscle defect in question. If the criteria are not exceeded the muscle is allowed to proceed unimpeded along the belt so that it falls down into the vessel 18 at the end of the belt intended for muscles without essential deviations.

By means of this transport and image processing equipment it is possible to perform two–sided determination of muscle surfaces and to sort the muscles into four different categories at a speed of one muscle every second, which corresponds to several batches of 1000 kg/h. This is satisfactory for production conditions, and so far this has not been attainable with any of the known systems.

Although the system cannot fully ensure that muscles with deviating characteristics are not included in the batch which is to be used for the production of cooked hams, it can after all sort out muscles with fairly large or distinct areas of defects, and all muscles will be examined, which is a very great improvement compared with the visual spot checks made today.

The arrangement in Fig. 3 for illumination of the meat on the belt and simultaneous recording of images in separate wavelength regions will now be described in further detail:

The arrangement includes a steel house 30 in the shape of four vertical walls and four inclined surfaces forming a sort of pyramid. The house is painted white inside. Located inside the house is a smaller, translucent house 31, which also has four vertical walls and four inclined surfaces which form a pyramid. The house 31 is made of semi–transparent, light–diffusing acrylic plates. Located in the space between the steel house 30 and the translucent house 31 are fluorescent tubes 32 with a total power consumption of approximately 1500 W. The fluorescent tubes are of the daylight type and they are supplied with a DC–voltage which can be adjusted manually.

The space between the two houses can be ventilated by means of ventilators 33 which suck in cold air from the surroundings. The warm air can escape through the top of the steel house via apertures 34. The ventilators are thermostatically controlled, so that the optimum temperature (approx. 31^0 C) for the fluorescent tubes and for a constant emission of light is maintain during the operation. Located in the space between the two houses can also be electric heating elements 35, which make sure that the fluorescent tubes attain their desired working temperature more quickly when the system is started up.

The pyramid roof of the house ends in a form of shaft or box 36 without bottom. Located in the box is a CCD-colour video camera of the three-chip type. The chips of the camera record images in the blue, green and red region, the light from the lens of the camera being distributed to the individual chips. Corresponding points (pixels) on the chips receive light from the same part of the muscle surface, and since the image recording takes place simultaneously in the three chips, the composite image is "colour-true". The usual colour video cameras with one chip and line filters produce images which are unacceptable in the present application. The camera is provided with a shutter set at 1/1000 of a second, and as described above it is activated by means of a sensor 23 which registers when a muscle is inside the field of view of the camera (indicated by the dotted line 37). The recorded image is transmitted analogously to the image processing unit 52, where it is stored by the frame-grapper and processed and analyzed for undesirable occurrences by means of the RISC-processor.

Located at one edge of the field of view 37 are three colour tiles 38, which have a well-defined colour and reflective power. The tiles are included on the recording, and their light/colour values are used in the computer to correct the images, as they serve as reference. If desired, it can be shown on the terminal 54 whether the tiles have a light value which deviates from the value prescribed, which can be a message to the operator to adjust the DC-voltage to the fluorescent tubes, so that they again emit the prescribed light. The adjustment can also be made automatically.

The inside of the box 36 is black like the conveyor belt 12 to avoid undesirable reflections.

The arrangement provides a very intense and at the same time homogeneous illumination of the muscles in the field of view of the camera, since there is only a little variation in time and from spot to spot in the field of view. In consequence of the location of the fluorescent tubes the illumination is strongest on the sides of the muscles and somewhat weaker on the top. However, the illumination is of a diffuse character, so that formation of shadows and reflections from the light sources are avoided.

As it appears from the above, the system is intended for a special application within the production of cooked hams. It is obvious, however, that the scope of the system is not limited to this application. The system can also be used within other areas after any appropriate modifications of the design.

If desired, the system in Fig. 1–3 can be used for sorting of muscles according to colour, muscle type and/or shape, and also less frequent defects, such as spots of blood and DFD, can be detected and included in the sorting process.

It is possible to simplify the system in connection with less demanding tasks. Thus, the section of the system shown in Fig. 1a can be left out, if the pieces of meat have already been separated from each other in another system or after they have been placed manually on the belt 12. Likewise, the sorting section can be left out, e.g. if the system is just used for quality control or if the sorting is made in another system. Furthermore, in many cases it may be sufficient just to record images of one side of the piece of meat, so that the turning belt 13 and the second image recording section are omitted.

Nor is it necessary for the pieces of meat being conveyed to lie on a belt, they can e.g. be located in a box with several other pieces of meat, so that several muscles are examined at the same time. Muscles with defects are detected by the system, which can give an alarm signal, and/or by means of e.g. light arrows it can send a message to an operator to remove these muscles from the box. If only a quantitative determination of the percentage of a certain surface type of the meat is required, the conveyance of the meat can proceed without separation. This is used e.g. in connection with fat determination of trimmings.

The following examples serve as additional illustration of the invention:

Example 1

Spectra of different types of surface:

On a section of the four main types of ham muscles ten spectra are recorded of each of the types of muscle surface: fat, membranes, PSE, pale meat, bloody meat, normal-colour meat. The muscle surfaces are oxidized. The spectra of the diffuse surface reflection of the muscle areas in the visible spectral region from 380 to 730 nm are measured by a spectrometer of the make Zeiss. The spectra achieved are shown in Fig. 4 (average reflection). At first it cannot be seen where in the spectral region the best differentiation between the types of surfaces is achieved.

Example 2

Statistical analysis of spectra:

The results of the spectral analyses in Example 1 are entered into the memory of a computer, and a calculation is made by means of a statistics programme in order to find the wavelengths by which the spectra produce the most information. Fig. 5 shows for the types of surface the calculated, proportional deviation from the mean spectrum. From the graph (and further calculations, if necessary) it can be seen that the detection of PSE and bloody surfaces is improved by moving the sensitivity in the blue region to 390–440 nm. Fat and pale meat are well distinguished by means of the green region (500–570 nm, like in the usual colour cameras), whereas bloody meat and PSE-meat are distinguished from other types of surface when the red region is moved to 620–700 nm.

Example 3

Establishment of a sorting table:

Images are recorded of different types of muscles by means of a colour camera of the three-chip type. The light from the object lens is split up/filtered, so that one chip registers the blue component, a second chip the green component, and a third chip the red component. Thus, the chips register a blue, a green and a red image, respectively. Each image has a resolution at 250 levels. The images are stored in an electronic memory.

A colour image composed by the three images is displayed on a monitor, on which an experienced operator marks the areas with normal-colour meat, pale meat, PSE-meat, etc.,

finding these areas on the muscle sample. The marked areas are stored in the memory along with the corresponding light values in the red, green and blue image.

A detection model is established following a mathematical analysis on the basis of a large number of muscles of a certain surface type. It consists of a three-dimensional colour space divided into regions, in which meat of normal colour is found within certain localities, pale meat within other localities, PSE-meat within others again, and so on. The light values in the red image are plotted along an axis, the light values in the green image along another axis, and the light values in the blue image along a third axis. The special thing about this is that each category of surface constitutes one or a few continua, which are not shared by other categories of surface. Instead of colour space you can also speak of tables or a three-dimensional matrix.

Such a detection model is preferably established for each type of muscle, and if desired, a model can even be established for each side of the muscle, in order to improve the accuracy of detection.

Examples of localities found are shown in Fig. 6-8, in which the figures specify the light intensity in the blue, green and red spectral region.

The detection model can be applied in connection with the system according to Fig. 1-3. Tests have shown that muscles with insufficient fat trimming, PSE and bloody areas can be sorted out with the necessary accuracy, even if the muscle has membranes or even if it consists of pale or dark meat, which it has not been possible so far to distinguish from the mentioned defects in connection with automatic production systems.

Claims

1. System for on-line determination of quality characteristics of pieces of meat for quality control or sorting, the system comprising: a conveyor with a belt (12,13,14) for conveyance of the pieces of meat (2), an arrangement of illumination (20,21) placed over the belt for illumination of the pieces of meat, a colour camera (22) placed in the arrangement for recording of three frames of the pieces of meat in the red, green and blue spectral region, and data equipment (51,52,53) for storage of the frames in the form of RGB-light values, analysis of the stored frames and determination of quality characteristics of the pieces of meat on the basis of the analysis, **characterized** in that the system comprises a three-chip CCD-colour camera which records frames in the red, green and blue region, each on an individual chip, and that the system is designed to record and store interdependent RGB-light values which originate from the same physical part of the piece of meat.

2. System according to claim 1, **characterized** in that the camera (22) is designed to record interdependent RGB-light values simultaneously.

3. System according to claim 1, **characterized** in that the data equipment includes a three-dimensional table which refers to a certain type of surface for each accepted combination of RGB-light values.

4. System according to claim 3, **characterized** in that the data equipment includes an application programme comparing stored, interdependent RGB-light values with the three-dimensional table installed in the data equipment and assigning the table's code for type of meat to each pixel in the composite image which contains an accepted combination of RGB-light values.

5. System according to claim 1, **characterized** in that the arrangement of illumination (20,21) provides a diffuse, spectro-neutral foreground illumination of the pieces of meat.

6. System according to claim 1, **characterized** in that the arrangement of illumination comprises a downwards open house, located along the walls of which are light sources, and that the arrangement includes devices for forced air circulation around the light sources.

7. System according to claim 1, **characterized** in that down-stream from the arrangement of illumination it comprises a second, corresponding arrangement of illumination provided with a camera, and that the conveyor between the arrangements has a belt section designed to turn a piece of meat around so that the side which was hidden from the camera of the first arrangement is now facing the camera of the second arrangement.

8. Method for on-line determination of quality characteristics of pieces of meat for quality control or sorting, the method comprising: conveyance of the pieces of meat (2) by means of a conveyor with a belt (12,13,14), illumination of the pieces of meat by means of an arrangement of illumination (20,21) located over the belt, recording of three frames of the pieces of meat in the red, green and blue region by means of a colour camera (22), which is located in the arrangement, storage of the frames in the form of RGB-light values, analysis of the stored frames, and determination of quality characteristics of the pieces of meat on the basis of the analysis, **characterized** in that frames in the red, green and blue region are recorded, each on an individual chip in a three-chip CCD-colour camera, and that interdependent RGB-light values which originate from the same physical part of the piece of meat are recorded and stored.

9. Method according to claim 8, **characterized** in that interdependent RGB-light values are recorded simultaneously.

10. Method according to claim 8, **characterized** in that stored, interdependent RGB-light values are compared with a three-dimensional table installed in the data equipment, which for each accepted combination of RGB-light values refers to a certain type of surface, and that each pixel in the composite image which contains an accepted combination of RGB-light values is assigned the table's code for type of meat.

11. Method according to claim 10, **characterized** in that the procedure is repeated for an essential part of the interdependent RGB-light values which originate from the piece of

meat, that the area of the composite image that depicts the piece of meat is segmented into areas with different types of surface, and that the piece of meat then is referred to a quality class with a view to quality control or sorting.

12. Method according to claim 8, **characterized** in that the light sources in the arrangement of illumination are kept at a constant temperature by forced air circulation around the light sources.

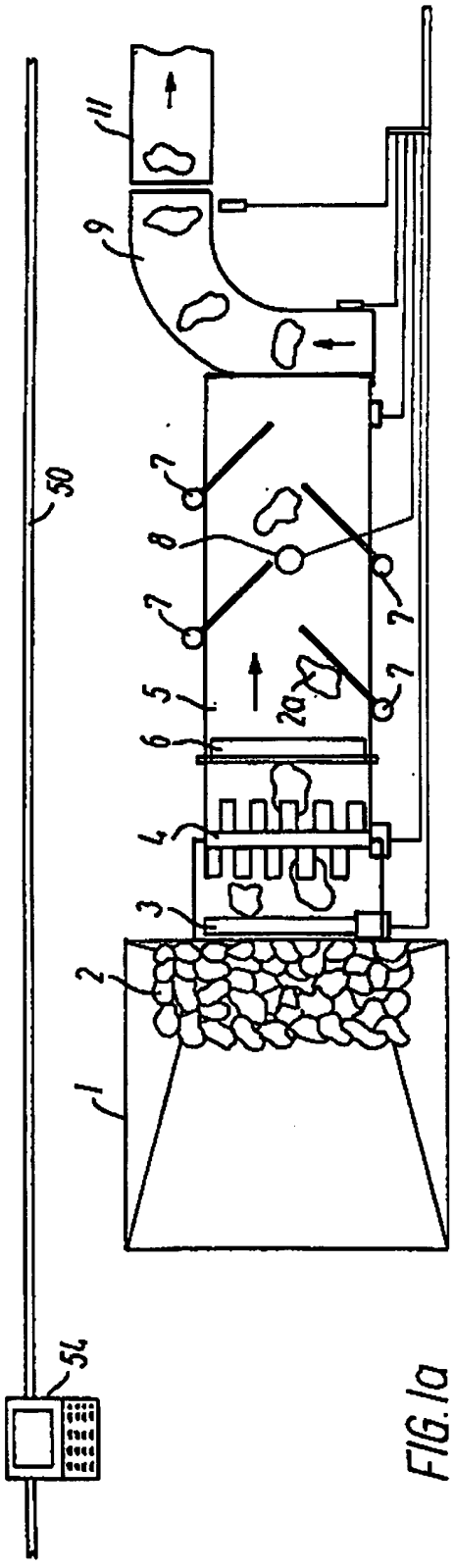
13. Method according to claim 8, **characterized** in that three additional frames of the piece of meat are recorded by means of a second camera with a corresponding arrangement of illumination, located down-stream from the first arrangement of illumination, and that the piece of meat is turned around so that the side which was hidden from the camera of the first arrangement is facing the camera of the second arrangement before the image recording.

14. Apparatus for on-line determination of quality characteristics of pieces of meat for quality control or sorting, the apparatus comprising: a conveyor with a belt (12,13,14) for conveyance of the pieces of meat (2), an arrangement of illumination (20,21) placed over the belt for illumination of the pieces of meat, a colour camera (22) located in the arrangement for recording of three frames of the pieces of meat in the red, green and blue region, and data equipment (51,52,53) for storage of the frames, analysis of the frames, and determination of quality characteristics of the pieces of meat on the basis of the analysis, **characterized** in that the apparatus down-stream from the arrangement of illumination comprises a second, corresponding arrangement of illumination with a camera, and that the conveyor between the arrangements has a section of the belt designed to turn the piece of meat around so that the side which was hidden from the camera of the first arrangement is now facing the camera of the second arrangement.

15. Apparatus according to claim 14, **characterized** in that the section of the belt (13) is lowered at its up-stream end compared with the belt which passes under the first arrangement.

16. Arrangement for illumination of pieces of meat which are conveyed on a conveyor belt in connection with the recording of images of the pieces of meat, the arrangement comprising: a downwards open house, located along the walls of which are light sources, characterized in that the arrangement is provided with devices for forced air circulation around the light sources.

17. Arrangement according to claim 16, characterized in that the devices comprise thermostatically controlled ventilators and/or heating elements.


11
9
50
7
8
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7
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20
6
4
3
2
1
54

FIG. 1a

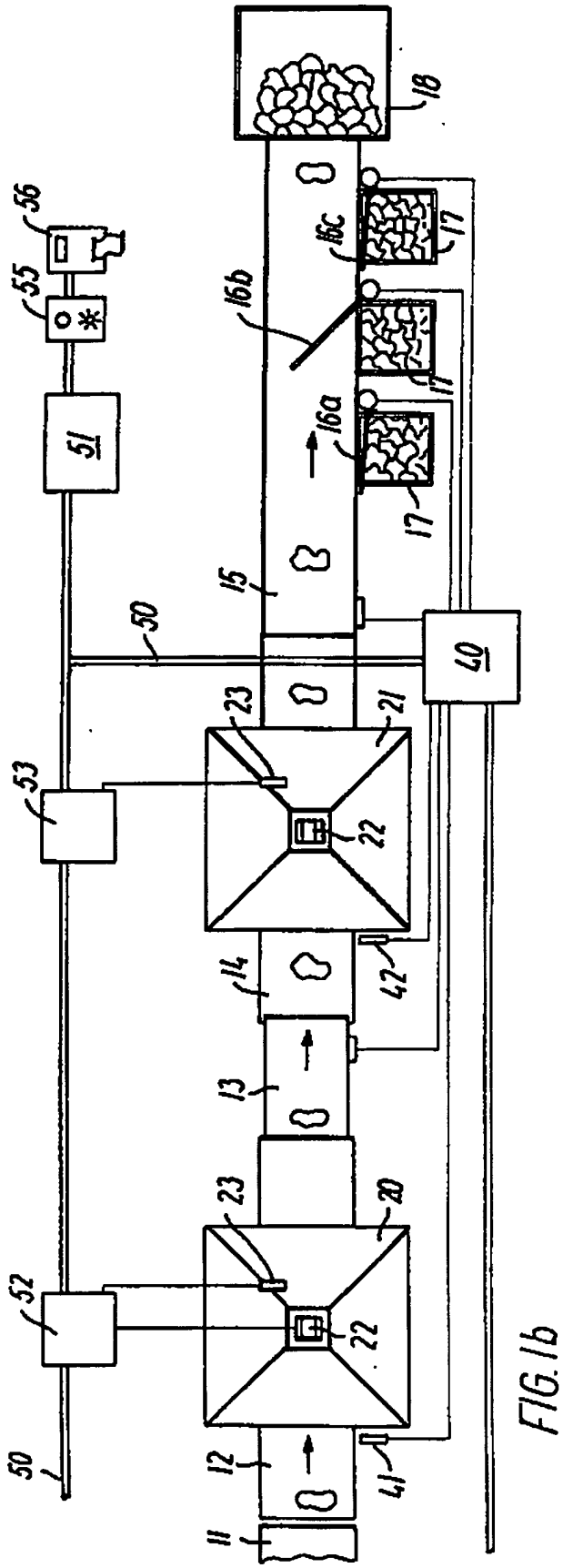

18
56
55
16c
17
16b
51
17
16a
17
15
50
40
23
21
53
22
14
42
13
23
20
52
22
12
41
50
11

FIG. 1b

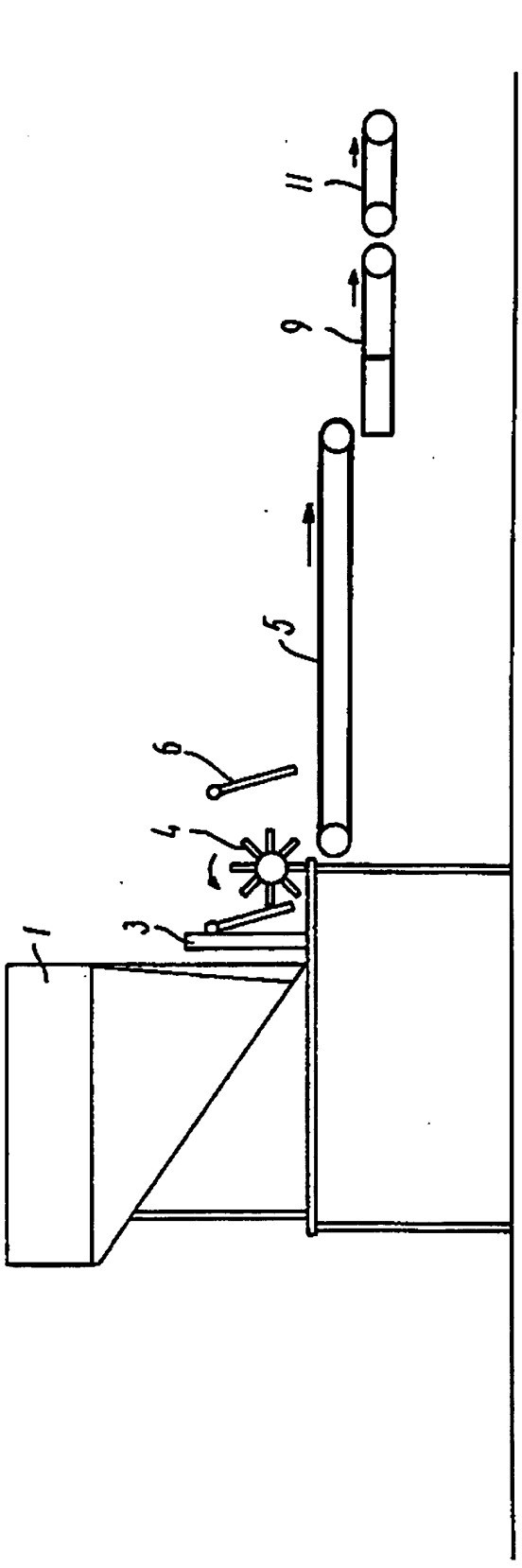


FIG. 2a

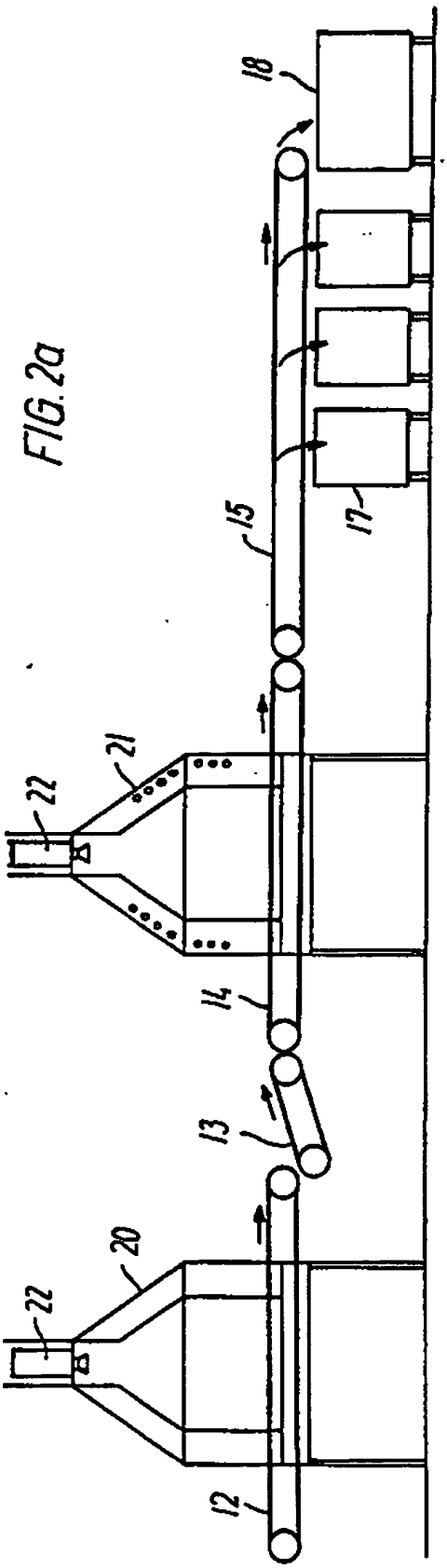


FIG. 2b

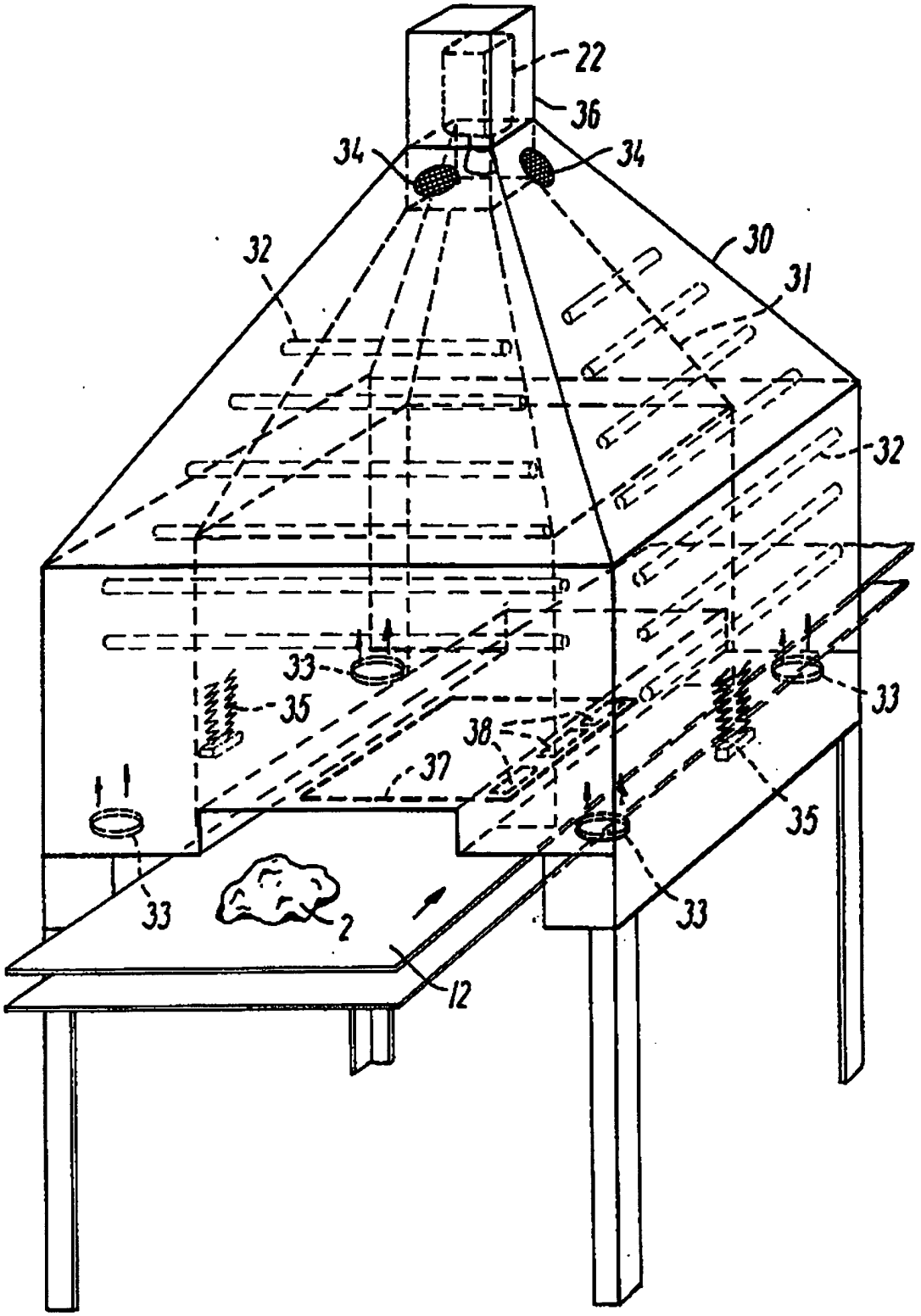
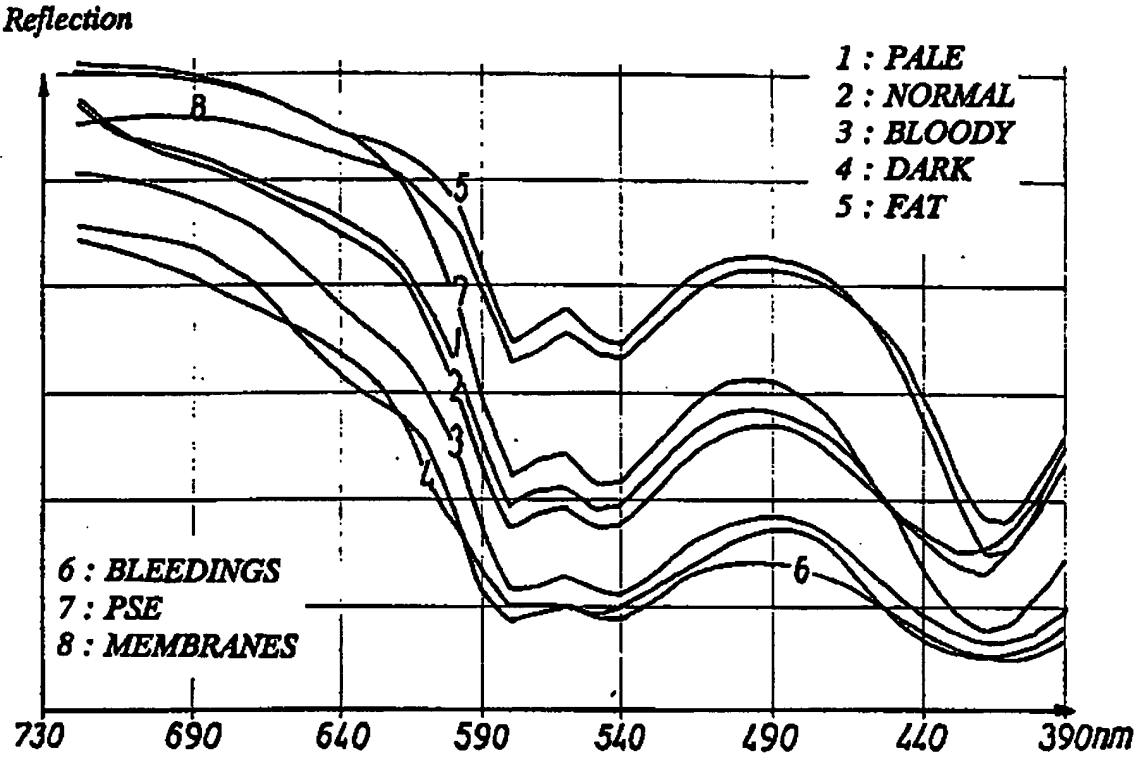


FIG. 3


Reflection
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2 : NORMAL
3 : BLOODY
4 : DARK
5 : FAT
6 : BLEEDINGS
7 : PSE
8 : MEMBRANES
730
690
640
590
540
490
440
390nm

FIG. 4

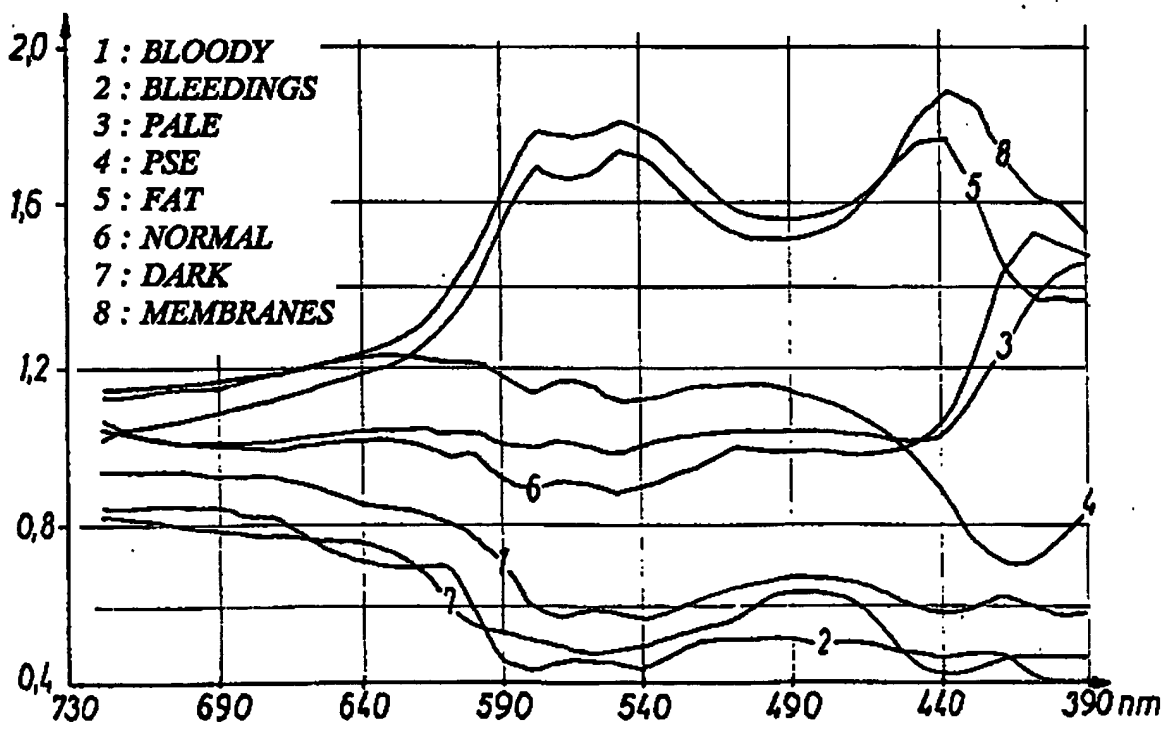
2,0
1,6
1,2
0,8
0,4
1 : BLOODY
2 : BLEEDINGS
3 : PALE
4 : PSE
5 : FAT
6 : NORMAL
7 : DARK
8 : MEMBRANES
730
690
640
590
540
490
440
390 nm

FIG. 5

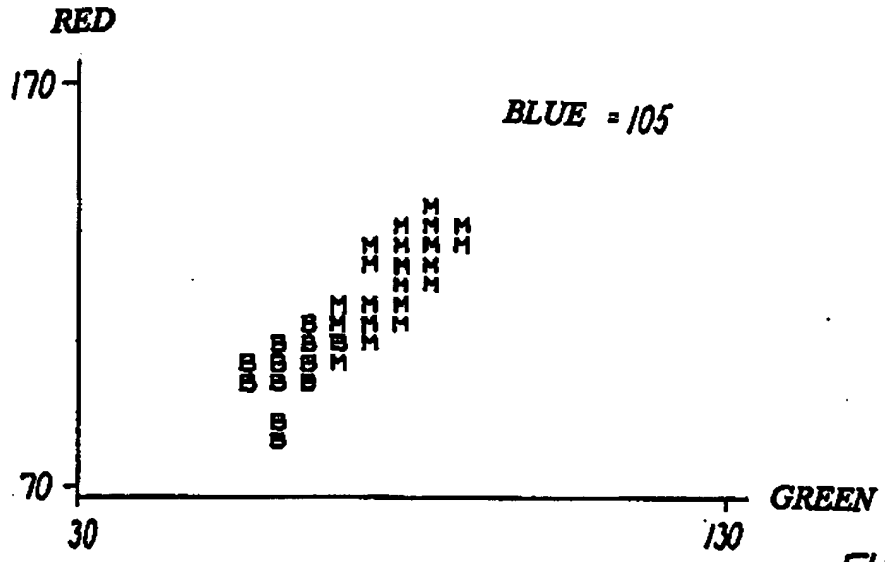

FIG.6a

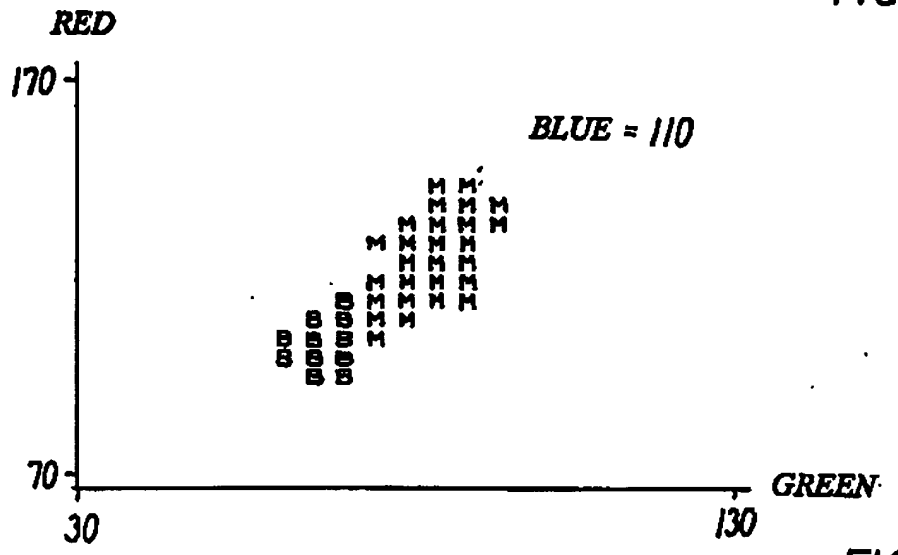

FIG.6b

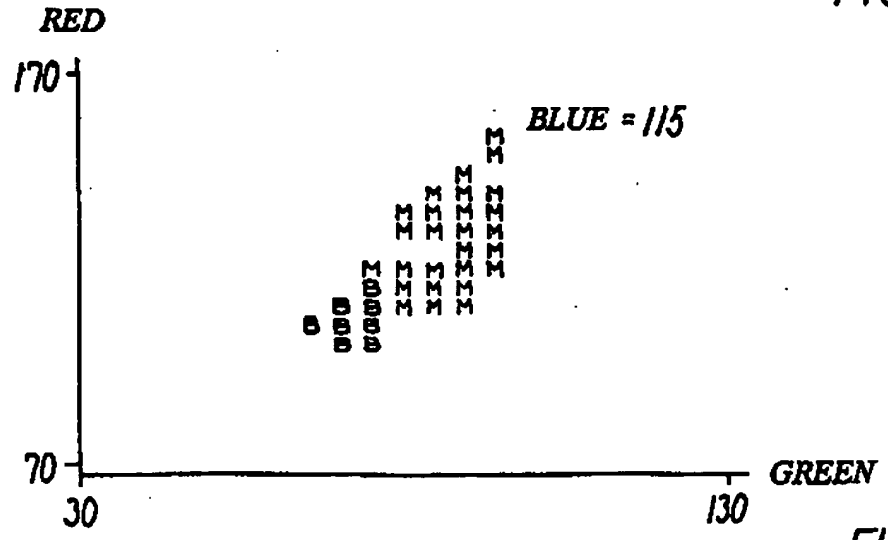

FIG.6c

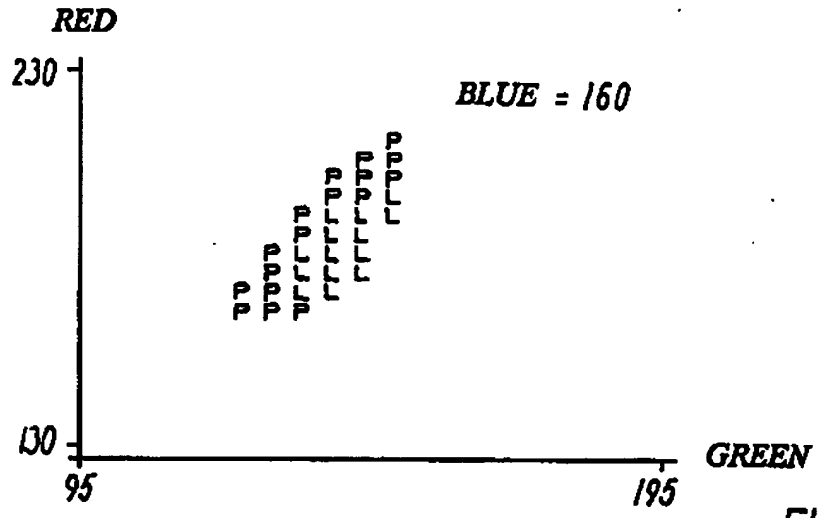

FIG. 7a

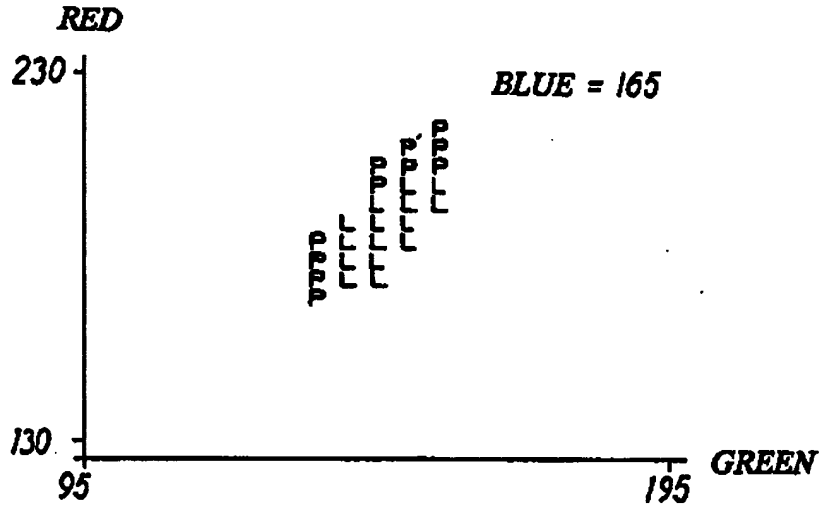

FIG. 7b

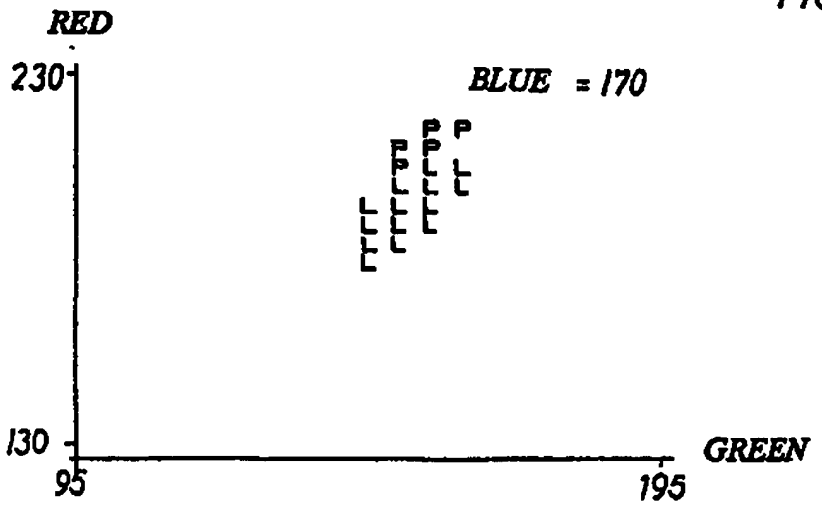

FIG. 7c

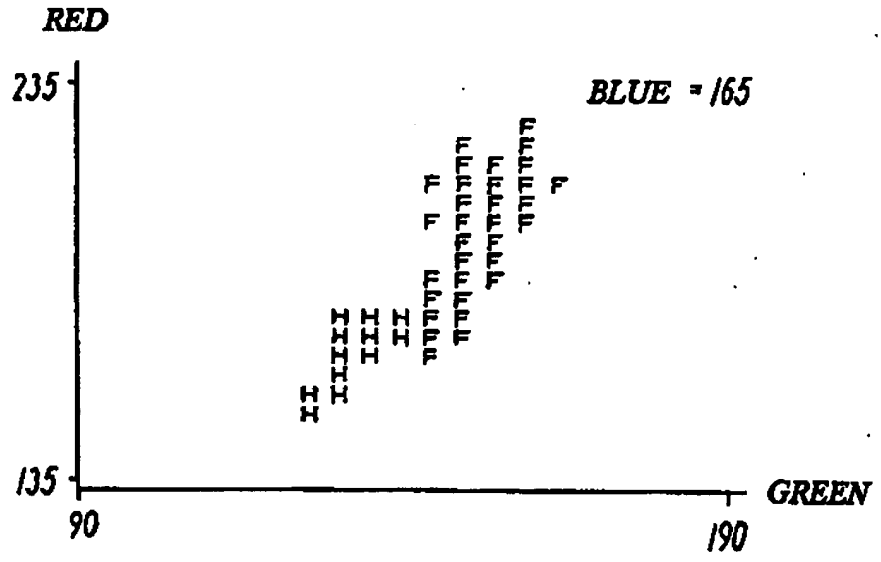

FIG.8a

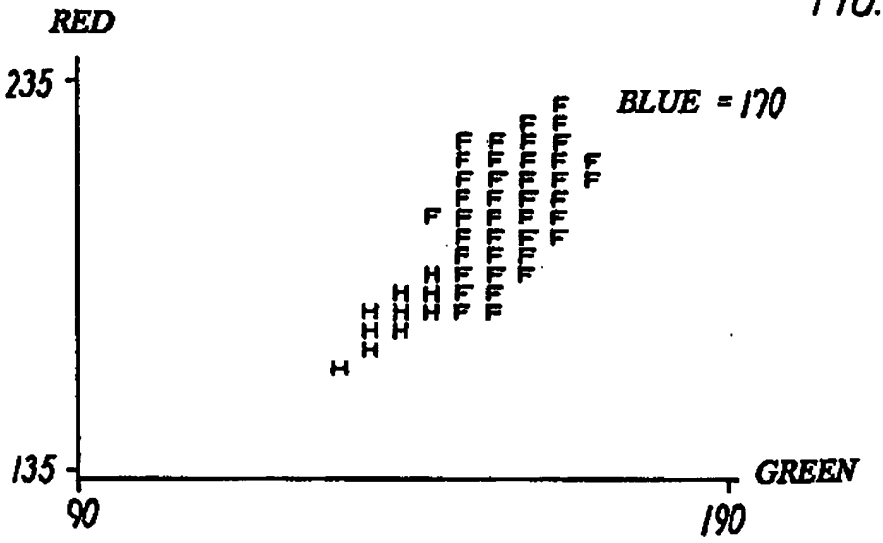

FIG.8b

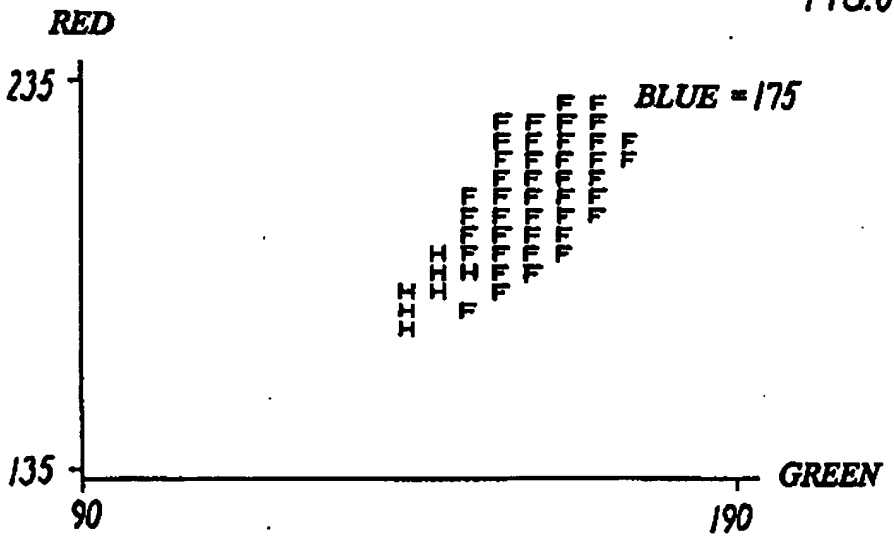

FIG.8c

INTERNATIONAL SEARCH REPORT

International application No.
DK 95/00046

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01N 21/27, G01N 33/12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, CLAIMS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO, A1, 9321597 (MEAT RESEARCH CORPORATION), 28 October 1993 (28.10.93), page 5, line 25 - page 7, line 25, figure 1, abstract --	1-15
Y	DK, B, 161049 (SLAGTERIERNES FORSKNINGSINSTITUT), 27 May 1991 (27.05.91), page 6, line 9 - line 31	1-13
X	figure 1, claims 2,3 --	16-17
Y	WO, A1, 9200523 (NATIONAL RESEARCH DEVELOPMENT CORPORATION), 9 January 1992 (09.01.92), page 3, line 2 - line 24, figure 7a, abstract --	14,15

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 April 1995	30 -05- 1995
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Karin Säfsten Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
[redacted]/DK 95/00046

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB, A, 2187281 (ANALYTICAL INSTRUMENTS LIMITED), 3 Sept 1987 (03.09.87), figure 1, abstract -- --------	1-17

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
DK 95/00046

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A1- 9321597	28/10/93	NONE	
DK-B- 161049	27/05/91	NONE	
WO-A1- 9200523	09/01/92	AU-A- 8052891	23/01/92
		EP-A- 0535125	07/04/93
		GB-A,B- 2247524	04/03/92
GB-A- 2187281	03/09/87	NONE	

INTERNATIONAL SEARCH REPORT

International application No.
[redacted]/DK 95/00046

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

I. Claims 1-15 directed to on-line quality-determination of meat, by storing and analysin the red, blue and green partial images of the meat.

II. Claims 16-17 directed to forced air-circulation around the light-sources.

These two groups of claims are not so linked as to form a single general inventive concept, and they do not present any common technical feature beyond the state of the art.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.